Electronic Money: Sustaining Low Inflation?

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Abstract

We analyze the impact of electronic money competition on policy outcomes. We consider different assumptions regarding the objectives of the central bank and its ability to commit to future policies. Electronic money competition can discipline a revenue maximizing government and result in lower equilibrium inflation rates, even when there is imperfect commitment. The efficient Friedman rule is only implemented if the government maximizes welfare. However electronic money competition may result in the Friedman rule being non credible. We also show how an independent choice of the reserve requirements can be an effective policy rule to enhance the disciplinary role of electronic money competition.

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1 Introduction

Technological change in transactions, such as the development in electronic payments, is blurring the distinction between different components of M1 (and among components of broader monetary aggregates). Does competition from interest-bearing inside moneys enhance price stability? An answer at first glance would be yes. However, one of the reasons for high equilibrium inflation rates is lack of commitment. And it is not clear that competition can solve the time consistency problem of monetary policy. In this paper we require the policy choices to be sequentially optimal and obtain a positive answer to the question in the title, while finding that competition and reputation do not reinforce each other.

Payments systems have gone through a major transformation in the last decade. In particular, electronic payments have risen in most developed countries and are expected to rise even more in the future. For example, Humphrey *et al.* (1996) find that "in all (fourteen) developed countries but the United States, electronic payments have been either the sole or the primary reason for the 34 percent rise in total non-cash payments between 1987 and 1993"(p. 935)[1]. Electronic money is deposits that are used for transactions through electronic payments. These payments have a low cost. In fact the clearing is considerably less expensive than the clearing of checks (1/2 to 1/3 according to Humphrey at al, 1996). They are highly substitutable for currency because the payment is ultimately a liability of the card issuing bank (checks, instead, are a liability of the purchaser). The purchases using cash cards are immediately deducted from a bank account that typically pays interest. This distinguishes electronic money from currency. Currency by its very nature cannot pay nominal interest. Instead, electronic money can pay nominal interest on the average balance at a very low cost.

The answer to the question whether competition in providing elec-

[1]The US is the exception because a larger fraction of non-cash transactions are paper transactions. As it will become clear, however, our definition of "electronic money" is fairly broad and encompasses most non-credit, non-cash, forms of payment, such as most bank cards, debit cards, smart cards, etc.

tronic money and competition between electronic money and currency drives down the price of money is also an empirical one, and it is tempting to relate the impressive reduction in inflation rates in the developed world to the generalization of electronic money as a means of payment. In fact most developed countries have experienced a drastic reduction of inflation rates in the last quarter of this century, from the double digit numbers of the mid-seventies to the very low –say, below 2.5%- numbers at the end of the nineties. High inflation episodes seem to be a problem of the past, as if society had become immune to the disease. This success in curbing inflation has usually been attributed to the major discipline, in terms of monetary policy, of more independent central banks and, in the case of the European Union, the design and willingness to comply with the Maastricht Treaty have received most of the credit. But maybe, the right incentives for monetary discipline have been created by the widespread development and use of cash substitutes.

The close substitutability of cash cards with currency makes this world with electronic money resemble a free banking world, i.e., the historical episodes of relatively unrestricted banking systems, as the "Free Banking Era" in the United States (1837-63), Scotland (1716-1844), New England (1820-1860), Canada (1817-1914) and other historical experiences[2]. In most cases, these episodes preceded the introduction of *legal restrictions* preventing the competition of privately issued bank notes. More recently, in many countries steps have been taken to liberalize financial services. But, more than to a pursuit of *laissez-faire*, the rise in electronic money is due to a technological change (not suppressed by regulations) which makes it possible for households and firms to consolidate their cash and deposits portfolios.

The issue of currencies competing in rates of return has also been addressed by an extensive literature[3] that focused on the currency sub-

[2]See Schuler (1992) for an account of historical episodes of free banking. See also Dowd (1992) and, in particular, the scholarly editorial work of White (1993) for a broad perspective of the literature on free banking; to which one must necessarily add the writings of Hayek (1974,1978).

[3]For a survey of the main results and the policy implications see Calvo and Vegh (1996). For a competitive equilibrium model exhibiting currency substitution, see

stitution experiences of high inflation countries. In those models government policies are exogenous.

In this paper we develop a theoretical framework to study the effects of electronic money competition —or, more generally, competition from interest-bearing inside monies. In particular, we study the relationship between competition and policy outcomes under different assumptions regarding the objectives of the central bank, the ability of the monetary authorities to commit to future policies, and the legal restrictions –in the form of reserve requirements– on financial intermediaries. The contribution of this paper is to show how these differences affect the way in which electronic money competition disciplines monetary authorities.

In interpreting the high inflation rates of the late seventies and early eighties, the literature emphasized the time inconsistency problem associated with monetary policy. Models with reputation have been developed to analyze this problem and some of the policy recommendations, like central bank independence, can be understood along these lines. The *time-inconsistency* problem in implementing monetary policies is well understood.

What is less clear is whether competition can help to overcome this problem, or whether it may even worsen it. In other words, the role of competition cannot be analyzed independently from the commitment problem. While we have begun to understand how policies can be designed in environments without full commitment (see, for example, Chang (1996), Chari & Kehoe (1990), Ireland (1994), Stokey, 1991), with –in part– the exception of Taub (1985) the "currency competition" argument has abstracted from the reputational problem[4]. This is the central theme of this paper.

In our model, "reputation" and "competition" are two disciplinary mechanisms that, as it turns out, do not always complement each other. To better understand this interplay, we study two contrasting hypothesis regarding the objectives of the central bank. First (in Sections 3, 4 and

Uribe (1997).

[4]A shortcoming that has not gone unnoticed (see, for example, Hellwig (1985)).

5) we assume a "revenue maximizing" central bank, second (in Section 6) a "representative" central bank; that is, a central bank which shares the same preferences as the representative household. The later hypothesis dominates the current academic literature on monetary policy design and is attractive to central bank economists. However, it is not clear which hypothesis is a better description of reality, and, therefore, we analyze both (leaving to the reader the exercise of taking convex combinations).

In Section 2 we present the model. In Section 3 we show how "electronic money" helps to curb down inflation when the government is a revenue maximizer. In the world with electronic money, the presence of money-issuing competitive banks drives the intermediation gains to the marginal intermediation cost. Inflation under full commitment is driven down as a result of competition between the issuer of currency and the anonymous suppliers of inside money, together with the reduction of financial intermediation costs.

In Section 4 we study the non-commitment case. The rent-seeking commitment policy is time inconsistent, but in considering default, the central bank must take into account that agents may move to electronic money (i.e., depriving the central bank of future seignorage rents). It turns out that, as long as there is no deflation under the full commitment policy, such a policy can be sustained by reputation. An odd feature of this result is that to sustain the full commitment policy, the financial intermediation sector cannot be too efficient. The interest rate spread between bonds and money must guarantee non-negative future rents to the central bank.

However, reserve requirements affect this spread. This, on the one hand, means that if reserve requirements are determined outside the central bank, they can be used as an effective policy instrument; but, on the other hand, it also means that if they are determined by the same central bank then the positive role of competition can be undermined. We analyze this in Section 5.

In Section 6 we study the case of a "representative" government. Not surprisingly, under perfect commitment, the Friedman rule is the policy chosen by the central bank (who acts as a Ramsey planner), therefore, there is no role for "electronic money" competition.

However, the Ramsey solution is time-inconsistent and, therefore, with imperfect commitment, the government must balance the gains of deviating from the prescribed Friedman rule, against the costs of a deviation. After a deviation, households do not use cash. When cash is the only liquid asset, this autarchic outcome is most undesired by the "representative" government. In contrast, the "punishment" is less severe when households can still use electronic money. As a result, the presence of electronic money competition makes the "reputation" disciplinary effect less effective. We show, however, that if agents cannot adjust their portfolios instantaneously, a benevolent government might be deterred from deviating and might implement the Friedman rule, in spite of the lack of commitment and the presence of electronic money competition. Section 7 concludes the paper.

2 Monetary competitive equilibria

In this section we characterize competitive equilibria in which transactions are performed with currency and electronic money. Electronic money is interest bearing deposits that are liquid because they can be used for transactions, through the use of electronic debit cards. Thus it is a close substitute for currency.

The economy is populated by a large number of identical infinitely lived households, financial intermediaries and a government. The households have preferences given by

$$V = \sum_{t=0}^{\infty} \beta^t [u(c_t^1) + u(c_t^2) + \alpha h_t] \tag{1}$$

where c_t^1, c_t^2 and h_t represent, respectively, consumption of a cash good, consumption of a credit good and leisure in period t. Assuming that leisure enters linearly in the utility function is in no way essential, but significantly simplifies the derivations. The utility function u shares the usual assumptions of concavity and differentiability.

The representative household chooses sequences of consumption of goods and leisure $\{c_t^1, c_t^2, h_t\}_{t=0}^{\infty}$ and sequences of assets $\left\{M_{t+1}, b_{t+1}^h, E_{t+1}\right\}_{t=0}^{\infty}$, given sequences of prices, $\left\{P_t, R_{t+1}^b, I_{t+1}^e\right\}_{t=0}^{\infty}$, to satisfy the following budget and cash-in advance constraints:

$$M_{t+1}+P_t b_{t+1}^h+E_{t+1} \leq M_t+P_t R_t^b b_t^h+I_t^e E_t-P_t(c_t^1+c_t^2)+P_t(1-h_t),\ t \geq 0 \tag{2}$$

$$P_t c_t^1 \leq M_t + E_t,\ t \geq 0 \tag{3}$$

where M_0, $R_0^b b_0^h$, and $I_0^e E_0$ are given and a no-Ponzi games condition is satisfied. The variable b_{t+1}^h denotes the number of units of the produced good, in period t, that entitle the household to $R_{t+1}^b b_{t+1}^h$ units of the produced good in period $t+1$. M_{t+1} is end of period currency held from period t to $t+1$. E_{t+1} is the electronic money. Currency and electronic money are perfect substitutes. I_{t+1}^e is the nominal rate of return on these deposits. $1-h_t$ is the labor supply and P_t is the price level. The particular timing is the one in Svensson (1985), meaning that the agents enter the period with money balances that are used for transactions that same period.

Since currency does not pay nominal interest, a competitive equilibrium where both currency and electronic money circulate must have $I_t^e = 1$. We define

$$I_{t+1}^b \equiv \frac{P_{t+1}}{P_t} R_{t+1}^b, \qquad t \geq 0 \tag{4}$$

Then an equilibrium in this economy must also satisfy:

$$\frac{u'(c_{t+1}^1)}{\alpha} = I_{t+1}^b, \qquad t \geq 0 \tag{5}$$

$$\frac{u'(c_t^2)}{\alpha} = 1, \qquad t \geq 0 \tag{6}$$

$$R_{t+1}^b = \beta^{-1}, \qquad t \geq 0 \tag{7}$$

If $I_t^e < 1$, only currency circulates and (5) - (7) must hold. If instead $I_t^e > 1$, then equation (5) is replaced by

$$\frac{u'(c_{t+1}^1)}{\alpha} = 1 + I_{t+1}^b - I_{t+1}^e, t \geq 0 \tag{8}$$

meaning that the cost of holding money is only the difference between the return on bonds and the return on money that in this case is not zero.

Financial intermediaries The financial intermediaries hold government bonds, $P_t b^e_{t+1}$, and issue interest bearing deposits that can be used for purchases, E_{t+1}, through the use of electronic debit cards. There is an intermediation cost measured in units of labor, n^e_t. We assume that the financial intermediaries operate a Leontieff-fixed coefficients technology that produces electronic money and uses as inputs bonds and labor. The total amount of electronic money equals the amount of bonds held and equals $P_t \frac{n^e_t}{\theta}$ where θ is the labor cost of one unit of deposits:

$$E_{t+1} = P_t b^e_{t+1}$$

$$n^e_t = \theta \frac{E_t}{P_t}$$

The cash flow of the financial intermediaries, in period t, is

$$CF^e_t = E_{t+1} - P_t b^e_{t+1} - E_t I^e_t + P_t b^e_t R^b_t - P_t n^e_t,\ t \geq 0 \tag{9}$$

The zero-profit condition is

$$I^b_{t+1} - I^e_{t+1} = \theta,\ t \geq 0 \tag{10}$$

Government The government issues money, M^s_{t+1}, and real debt, d_{t+1}, to finance government expenditures, g_t. Government expenditures are a credit good. We abstract from alternative sources of tax revenues so that the government budget constraints are

$$M^s_{t+1} + P_t d_{t+1} \leq M^s_t + P_t R^b_t d_t + P_t g_t,\ t \geq 0 \tag{11}$$

The present value budget constraint can be written as

$$\sum_{t=0}^{\infty} q_t g_t \leq \sum_{t=0}^{\infty} q_{t+1}(I^b_{t+1} - 1)\frac{M^s_{t+1}}{P_{t+1}} - \frac{M_0}{P_0} - R^b_0 d_0 \tag{12}$$

where $q_t = \frac{1}{R^b_1 \ldots R^b_t}$, $t \geq 1$, $q_0 = 1$.

Market clearing The market clearing conditions are

$$c_t^1 + c_t^2 + g_t = 1 - h_t - \theta \frac{E_t}{P_t} \ , t \geq 0 \tag{13}$$

$$d_t = b_t^h + b_t^e \ , t \geq 0 \tag{14}$$

$$M_t = M_t^s \ , t \geq 0 \tag{15}$$

The competitive equilibrium where both currency and electronic money circulate must satisfy:

$$I_{t+1}^b = 1 + \theta \tag{16}$$

In this equilibrium the real values of currency and electronic money are indeterminate. Therefore the level of government expenditures is also indeterminate. For the utility function that is linear in leisure, consumption is determinate but leisure is not. To abstract from this indeterminacy we assume that when the cost of holding the two types of money is equal, the households opt for currency.

If $I_t^e > 1$, only electronic money circulates. The price level and the nominal interest rates are indeterminate. The real variables are not affected by the multiplicity in the price levels and the nominal interest rates.

In these economies with private issuers of electronic money, the nominal interest rates are not driven down to zero. The reason is that private issuance of electronic money is compatible with interest payments on money, whereas that literature tended to exclude this possibility. Free entry into this market drives the spread between the rate on bonds and the rate on electronic money down to the cost of supplying the monetary substitutes. Competition between electronic money and currency can itself drive down the interest rates, as will be shown in the next section.

3 Equilibria with commitment

In this section we consider full commitment optimal policies under the assumption that the government maximizes revenue. Thus, we assume that the government preferences are described by an objective function

$$\sum_{t=0}^{\infty} \beta^t G(g_t)$$

where, for standard reasons, the function G is assumed to be increasing and concave. The government maximizes this function subject to the budget constraint and subject to the competitive equilibrium conditions by choice of $\{M_t^s,\, d_t,\, g_t\}_{t=0}^{\infty}$.

First, note from equation (7) that the equilibrium real rate of interest is constant[5]. Using this result together with (4), (5) and (6) to eliminate prices in the government budget constraint (12) we obtain the following implementability constraint

$$\sum_{t=0}^{\infty} \beta^t g_t = \sum_{t=0}^{\infty} \beta^{t+1}(I_{t+1}^b - 1)F(I_{t+1}^b) - \frac{M_0}{P_0} - R_0^b d_0$$

where F is real demand for currency. If the government chooses $I_{t+1}^b \leq 1+\theta$, so that only currency circulates, then $F = M$, where M is the function obtained from the first order condition $\frac{u'(c_{t+1}^1)}{\alpha} = I_{t+1}^b$, so that $c_{t+1}^1 = m_{t+1} = M(I_{t+1}^b)$. If instead ${I^b}_{t+1} > 1+\theta$, then $F(I_{t+1}^b) = 0$. The government maximizes revenues by setting the monetary policy so that $\frac{M_0}{P_0} = 0$.

Given that G is assumed to be strictly concave and that the discount factor of the government is equal to the real interest rate, the government's problem can be simplified as the choice of a sequence of nominal interest rates that maximizes

$$g = (1-\beta)\sum_{t=0}^{\infty} \beta^{t+1}(I_{t+1}^b - 1)F(I_{t+1}^b) - (1-\beta)R_0^b d_0 \tag{17}$$

If in the objective function we replace the function F for M so that there are no constraints on the choice of the nominal interest rates arising

[5]This results from the linear structure of the utility function. Note that this assumption rules out the time inconsistency problem discussed in Lucas and Stokey (1983).

from competition with electronic money, the solution is stationary and corresponds to the maximum of the Laffer curve, I^{b*}. For the isoelastic utility function, $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, with $\sigma < 1$, as I^b_{t+1} becomes arbitrarily large, the revenue $(I^b_{t+1} - 1)M(I^b_{t+1})$ tends to zero. Also when $I^b_{t+1} = 1$, the revenue is zero. The maximum of the Laffer curve corresponds to a positive, finite value for the interest rate. We assume that the preferences specification is such that the value I^{b*} is higher than $1 + \theta$. This means that the revenue maximizer government would not choose an interest rate lower than that value. Should the government choose $I^b_{t+1} > 1+\theta$? In this case the revenue is zero. So the government will choose $I^b_{t+1} = 1+\theta$, for all $t \geq 0$, and raise $\theta F(1 + \theta)$ of seigniorage revenue, per period. Since from the zero profit condition for the financial intermediaries $I^b_{t+1} = I^e_{t+1} + \theta$, it must be that $I^e_{t+1} = 1$. We have shown that the following proposition holds:

Proposition 1 *Assume $I^{b*} \geq 1+\theta$, where I^{b*} maximizes $(I^b - 1)M(I^b)$. Then the commitment solution for the revenue maximizing government is $I^b_{t+1} = 1 + \theta$, and $I^e_{t+1} = 1$, for all $t \geq 0$.*

Electronic money drives the nominal interest rates to levels that only account for the intermediation cost, i.e. the cost of providing the alternative means of transactions to the households. In an environment without electronic money, the government would set the monetary policy so that the maximum revenue may be obtained. This would mean that the interest rate would be I^{b*}, and the revenues would be $g = \beta(I^{b*} - 1)F(I^{b*}) - (1 - \beta)R^b_0 d_0$. Since government revenues are assumed to be worthless, the presence of electronic money is welfare improving.

Would the same result be obtained if regulation prevented the banks from paying interest on electronic-money? Apparently yes, since the resulting equilibrium is precisely zero interest on electronic-money. In fact no, since it is assumed, that for equal prices the private agents opt for the government currency. If banks could not pay a higher return on electronic-money than on currency, then the central bank is free to charge any price on currency.

The optimal commitment solution is time inconsistent. In this solution, at time zero, the government decides to hold real bonds issued by the private sector that are exchanged for money and the gross nominal interest rate is constant over time and set at $1+\theta$. At time t, if the government could revise the plan, the problem would be to choose $\left\{I_{s+1}^{b}\right\}_{s=t}^{\infty}$ to maximize

$$g^{t}=(1-\beta)\sum_{s=t}^{\infty}\beta^{s+1-t}(I_{s+1}^{b}-1)F(I_{s+1}^{b})-(1-\beta)\left[\frac{M_t}{P_t}+\beta^{-1}d_t\right] \quad (18)$$

where g^t are the government expenditures from period t on. The optimal policy is to set the price level at time t arbitrarily large. This way the government reduces the real value of the nominal liabilities. So the interest rate plan for $I_t^b=\frac{P_t}{\beta P_{t-1}}=1+\theta$ would not be optimal, for a government that could decide sequentially.

The discussion above suggests that lack of commitment can drastically change the nature of currency competition. In fact, the governmental agency that issues currency competes with the private issuers of money by announcing an interest rate. However, as was shown above, the equilibrium nominal interest rates, under commitment, are not time consistent and therefore those announcements make no sense. As a result, one could be led to think that an equilibrium with electronic money-only would be the sole sequential equilibrium outcome. In fact this is not the case. The credible threat of reversion to an equilibrium where currency does not circulate might be enough to sustain the equilibrium solution under commitment that was just described.

This means that currency competition when there is at least one big player, that can influence the price level, is of a very different nature from competition under commitment. In Section 4, we determine the sequential equilibria in an environment where the government precisely cannot commit to the announced policy.

4 Equilibria without commitment

As it is clear from the discussion in the last section, the government policies are not time consistent. Thus, in this section we consider reputational equilibria where the competitive households and financial intermediaries condition their decisions on the contemporaneous histories of government policies. This framework naturally drives the analysis to the interactions between competition and reputation.

Once we allow expectations of the agents to depend on histories, there is always an equilibrium where only electronic money circulates. This equilibrium is time consistent. The households expect that the return on electronic money is higher than the one on currency, $I^b_{s+1} > 1+\theta$, $s \geq t$, and the real value of currency they decide to hold is equal to zero. Given this the demand for real balances is zero and any monetary policy is optimal. In particular, having a monetary policy of high interest rates, consistent with agents' expectations, is a best reply for the government. Since $F(I^b_{s+1}) = 0$, $s \geq t$, and $\frac{M_t}{P_t} = 0$, then the value of this equilibrium outcome is

$$V_t^{WSE} = -(1-\beta)R^b_t d_t$$

where WSE stands for worst sequential equilibrium. We do show now that this is indeed the worst.

Note that a feasible policy for the government, at any time is to follow a constant money rule. Under these conditions there are two stationary equilibria, one where prices are finite and constant, and another one where the real balances are zero. There may also be other equilibria where the price level grows without bound. In any of these equilibria, either $F(I)$ is zero or it is positive and $I_t \geq 1$. The value for the government is given by (17). Every term in the summation on the right hand side is either positive or zero. In this case, independently of what the private agents' optimal response is, the government can achieve, at least the value V_t^{WSE}. In the language of game theory, this is the reservation value (minimax strategy) for the government. Therefore, there cannot be a sequential equilibrium with a value lower than V_t^{WSE}.

The above argument shows that a monetary policy where, following an arbitrary increase of the price level (say, to infinity), interest rates are high enough, consistent with private sector's beliefs, and cash is not held, is a Nash equilibrium. To define a policy, resulting in a sub-game perfect (and sequential) equilibrium, we must define how the government will behave in the –zero probability– event that some agents demand cash anyway. In such case, we postulate that the revenue maximizing government will set the price arbitrarily large (defaulting, again, on outstanding liabilities) and setting interest rates, after that, as to have cash (asset) return dominated by electronic money. Notice that in such a –zero probability– path, interest rates become arbitrarily large too.

In the tradition of Barro and Gordon (1983) and in line with Chari and Kehoe(1990), Stokey (1991), Ireland (1994) and Chang (1996), we apply Abreu (1988)'s optimal penal codes and use the reversion to the worst sequential equilibrium as the means of supporting equilibrium outcomes. The value of the worst sequential equilibrium outcome is compared to the value of the revenue maximizing equilibrium (RME) outcome,

$$V_t^{RME} = \beta(I^b - 1)M(I^b) - (1-\beta)\left(M(I^b) + R_t^b d_t\right)$$

where $I^b = 1 + \theta$. The RME equilibrium path can be supported as a sequential equilibrium when its value is higher then the one of the WSE. This is true when

$$\pi \geq 0$$

meaning that the government has to get a positive gain from issuing money. The proposition follows:

Proposition 2 *The optimal policy under commitment is a sequential equilibrium path if the intermediation cost, θ, is large enough that the equilibrium inflation rate is non-negative.*

Proof. It was shown above that the optimal policy under commitment is a sequential equilibrium whenever $\pi \geq 0$. This means that $I^b \geq \beta^{-1}$. But $I^b = 1 + \theta$. So it is necessary that $\theta \geq \beta^{-1} - 1$ ■

This result is not surprising if you think of seigniorage revenue accounting. The total seigniorage revenue can be split in two parts: the gains from lending out the real quantity of money (at the real interest rate) plus the gains from issuing new money (the inflation rate). If the government defaults, the outstanding balances are valueless and there are no future seigniorage revenues. If instead, there is no default, then the gains are just the ones from future issuance of money. As long as these are positive, meaning that the inflation rate is positive, it is optimal for the central bank to stay in business.

In a world without electronic money, the commitment solution would be to set the nominal interest rate so that the maximum of the Laffer curve is obtained. As long as this value is positive, the equilibrium is sequential. In this case, the punishment is autarchy, but from the perspective of a revenue maximizing government, this has the same value as the electronic money-only equilibrium.

One could think that competition with electronic money would drive the nominal interest rates to values that could not be sustained, because the opportunity cost of defaulting would be substantially reduced. This is partially true. Competition with electronic money drives the inflation tax to a low level under commitment, but this solution is a sequential equilibrium provided the intermediation cost is big enough, to guarantee the benefits from the future issuing of currency.

If the commitment solution is not a sequential equilibrium then the only sequential equilibrium path is the equilibrium without currency. However since currency is replaced by electronic money this "autarchic" solution may not be such a great disaster. In the way we have modelled money, there is a liquidity effect so that the switch to electronic money implies the destruction of the real value of liquid assets and so the cash good is not consumed in that period. However from the following period on the households would be using electronic money as the means of exchange, supporting the cost of intermediation.

We have seen that the requirement for the commitment solution to be sequential is that the intermediation costs are not too low. One way of guaranteeing that these costs are big enough is to establish reserve requirements. That way competition with electronic money is made softer and so the revenues from issuing money may be increased to the point that the revenue maximizing government is not interested in defaulting. In the next section we analyze the effects of considering reserve requirements, for the equilibria with and without commitment.

5 Reserve requirements

Reserve requirements can be understood as a technological constraint or instead as a legal requirement. We assume that, as it is in most cases, legal requirements on idle reserves are a fraction of total deposits. Therefore every bank faces a fixed coefficients technology with deposits, labor input and reserves, such that

$$(1-z)E_{t+1} = P_t b^e_{t+1}$$

$$Z_{t+1} = zE_{t+1}$$

$$P_t n^e_t = \theta E_t$$

where Z_{t+1} are reserves and z is the linear reserve requirement. In period t, the cash flow of the financial intermediaries is

$$CF^e_t = E_{t+1} - P_t b^e_{t+1} - Z_{t+1} - E_t I^e_t + P_t b^e_t R^b_t + Z_t - \theta E_t,\ t \geq 0 \quad (19)$$

The zero profit condition is therefore

$$I^b_{t+1} - I^e_{t+1} = \theta + z(I^b_{t+1} - 1),\ t \geq 0 \quad (20)$$

The government budget constraint is not affected by the presence of the reserve requirements, but the government money supply must now, in equilibrium, be equal to the demand by the households and by the financial intermediaries.

$$M_t + Z_t = M^s_t\ ,\ t \geq 0 \quad (21)$$

The competitive equilibrium where both currency and electronic money can circulate must now satisfy:

$$I_{t+1}^b = 1 + \frac{\theta}{1-z} \tag{22}$$

The government budget constraint can be written as

$$\sum_{t=0}^{\infty} \beta^t g_t \leq \sum_{t=0}^{\infty} \beta^{t+1} (I_{t+1}^b - 1) F(I_{t+1}^b) - \frac{M_0}{P_0} - \frac{Z_0}{P_0} - R_0^b d_0 \tag{23}$$

where F is the real demand for currency and reserves. If the government chooses ${I^b}_{t+1} \leq 1 + \frac{\theta}{1-z}$, so that only currency circulates, then again $F = M$, where M is the function $m_{t+1} = M(I_{t+1}^b)$, obtained from the first order condition $\frac{u'(m_{t+1})}{\alpha} = I_{t+1}^b$. If instead ${I^b}_{t+1} > 1 + \frac{\theta}{1-z}$, then, using (20),

$$F(I_{t+1}^b) = zM(1 + \theta + z({I^b}_{t+1} - 1)).$$

Note first that reserve requirements do not change the nature of the problem concerning the period zero balances. Therefore, the government maximizes revenues by setting the monetary policy so that $\frac{M_0}{P_0} = \frac{Z_0}{P_0} = 0$. The government's problem can be simplified as the choice of a sequence of nominal interest rates that maximizes

$$g = (1-\beta) \sum_{t=0}^{\infty} \beta^{t+1} (I_{t+1}^b - 1) F(I_{t+1}^b) - (1-\beta) R_0^b d_0 \tag{24}$$

If the reserve requirement, z, is taken to be exogenous, there are three types of solutions. First, if the intermediation cost, θ, is very low, eventually zero, then, for currency to circulate, the nominal interest rate must be very low. Therefore, the government cannot get almost any seigniorage revenue from currency. In this case, the solution is to set a nominal interest rate such that only electronic money circulates, and that maximizes the seigniorage imposed on reserve requirements, the only demand for currency in the equilibrium. Therefore, the government maximizes

$$z(I^b - 1)M(1 + z(I^b - 1)).$$

This means that the choice of the nominal interest rate is $I^b = \frac{I^{b*}-(1-z)}{z}$ where I^{b*} is the interest rate that maximizes the Laffer curve, defined as $(I^b - 1)M(I^b)$.

A second possible solution can occur for intermediate values of θ and z. This is a case in which the maximum of the Laffer curve is to the right of $1 + \frac{\theta}{1-z}$. Thus, electronic money does impose an upper bound on the nominal interest rate. However, the government is better off by imposing a low– relative to the maximum of the Laffer curve –interest rate but having a larger tax base, rather than imposing a higher interest rate but collecting the tax on a fraction of the money in circulation. In this case, the solution is the corner $I^b = 1 + \frac{\theta}{1-z}$. Here only currency circulates, as well.

Finally, if θ and z are high enough, it might be that $I^{b*} < 1 + \frac{\theta}{1-z}$, in which case I^{b*} will be the solution, and only currency circulates. The value of this solution is $g = \beta(I^{b*} - 1)M(I^{b*}) - (1-\beta)R_0^b d_0$. In this case, the intermediation costs combined with the reserve requirements imply that electronic money cannot compete with currency.

If the same agency that picks the inflation tax also determines the reserve requirements, then the optimal solution is to set z, so that

$$1 + \frac{\theta}{1-z} = I^{b*}$$

In this case the government gets the revenue corresponding to the maximum of the Laffer curve and only currency circulates[6].

The presence of reserve requirements, by forcing the banks to hold non-interest bearing assets, has the effect of softening the competition with electronic money. In the extreme case of a 100% reserve requirement, electronic money competition is killed.

Note that with reserve requirements, the condition for currency to dominate electronic money becomes

[6]If the intermediation cost was zero then this solution could be reproduced by establishing complete backing, $z = 1$, and setting the nominal interest rate to I^{b*}.

$$I^b \leq 1 + \frac{\theta}{1-z}$$

Therefore, from the viewpoint of the government, an economy with intermediation costs equal to θ and reserve requirements equal to z is equivalent to an economy without reserve requirements and an intermediation cost equal to

$$\theta' = \frac{\theta}{1-z}$$

The solution with an endogenous reserve requirement corresponds to the maximum of the Laffer curve so it is equivalent to the solution without electronic money. In that case the non-committed government is able to sustain a high level of the inflation tax.

For any exogenous level of the reserve requirement, if the commitment equilibrium is such that only currency circulates, then the punishment is to revert to electronic money but with arbitrarily large nominal interest rates so that the solution is autarchy. So for the revenue maximizing government the effect of the reserve requirements is to raise the value of the equilibria under commitment, improving the conditions for sustainability of the equilibria. This result is summarized in the following proposition:

Proposition 3 *Whenever $\theta < \beta^{-1} - 1$, it is possible to sustain an equilibrium solution under commitment if the reserve requirements are high enough, as long as the inflation rate that maximizes the Laffer curve is non-negative.*

Proof. Let the reserve requirement z be such that $1 + \frac{\theta}{1-z} = \beta^{-1}$. If the inflation rate that maximizes the Laffer curve is non-negative, the equilibrium under commitment for the interest rate must be $I^b \geq \beta^{-1}$, since the government can at least get the revenues from the currency-only equilibrium with $I^b = \beta^{-1}$. As we showed in the previous proposition, the currency-only equilibrium is sequential as long as the equilibrium inflation rate is non-negative, i.e $I^b \geq \beta^{-1}$. Since the case where $I^b > \beta^{-1}$ must correspond to higher revenues, the equilibrium under commitment is sustainable ■

5.0.1 Reserve requirements as a policy tool

Reserve requirements can act as a means of guaranteeing the sustainability of the commitment solution for the revenue maximizing government. If the commitment solution is not sustainable the solution will be the autarchic equilibrium that is a sequential equilibrium. In terms of welfare in this case with reserve requirements the punishment is very severe, since the households can reduce the revenues to the government only by driving electronic money out of circulation. The households would be better off paying the inflation tax that brings the highest revenue to the government. The endogeneity of the reserve requirement, softens the asymmetry of the punishment to the households and to the government since it would be an off-equilibrium outcome.

An obvious policy recommendation is the careful and independent use of the reserve requirement instrument as a means of obtaining sustainability of the revenue maximizing, commitment solution.

6 The case of a "representative" government

In this section we briefly show how the results change when we assume that the government maximizes the utility function of the consumers. The standard Ramsey problem assumes fixed government expenditures. As the ability to collect seigniorage will be limited by the efficiency of the financial intermediaries, we allow the government to levy consumption taxes, τ_t, to ensure that expenditures can be financed. As we will see, a "representative" government with full commitment, will obey optimal taxation principles and implement the Friedman principle of zero nominal interest rates after the initial period. It also may want to tax relatively more the first period cash good by increasing the initial price level (as we will see, whether or not the government wants to do this, depends on the price elasticity of the consumption good). This is the basis of the time inconsistency of the optimal monetary policy. Before analyzing policies without full commitment, we must characterize equilibria with electronic money and the Ramsey –full commitment– solution.

The consumer's problem is as before, except for the presence of a tax on consumption. Thus, preferences are represented by

$$V = \sum_{t=0}^{\infty} \beta^t [u(c_t^1) + u(c_t^2) + \alpha h_t]$$

We simplify the analysis of this section by assuming *Constant Relative Risk Aversion (CRRA)*. That is, $-\frac{u''(c_t)c_t}{u'(c_t)} = \sigma$, where $1/\sigma$ is the price elasticity of c_t. For simplicity we also assume that $\sigma \leq 1$. The budget and cash-in-advance constraints are

$$M_{t+1} + p_t b_{t+1}^h + E_{t+1} \leq p_t(1-h_t) - (1+\tau_t)p_t(c_t^1 + c_t^2) + M_t + p_t R_t^b b_t^h + I_t^e E_t \tag{25}$$

$$(1+\tau_t)p_t c_t^1 \leq M_t + E_t \tag{26}$$

It follows that the solution of the households problem must +satisfy:

$$p_t = \beta^t \lambda_t^{-1} \alpha \tag{27}$$

where λ_t is the lagrange multiplier associated with the budget constraint (25), and

$$1 + \tau_t = \frac{u'(c_t^2)}{\alpha} \qquad t \geq 0 \tag{28}$$

Furthermore, if $I_{t+1}^e \leq 1$,

$$I_{t+1}^b = \frac{u'(c_{t+1}^1)}{u'(c_{t+1}^2)} \qquad t \geq 0 \tag{29}$$

while if $I_{t+1}^e > 1$,

$$\frac{u'(c_{t+1}^1)}{u'(c_{t+1}^2)} = 1 + I_{t+1}^b - I_{t+1}^e = (1+\theta) \qquad t \geq 0 \tag{30}$$

where the last equality follows from the zero profit condition in financial intermediation.

6.1 Optimal policy under commitment

The solution under commitment is a Ramsey (1927) optimal taxation problem, in the line developed by Lucas and Stokey (1983) and Chari, Christiano and Kehoe (1993); as them, we follow the –so called– *primal approach*. The objective of the government is to maximize the welfare of the representative household, subject to feasibility and competitive equilibrium constraints; in the *primal approach*, these competitive equilibrium constraints are consolidated in a unique *implementability constraint*.

More precisely, consider first the case where $I^e_{t+1} \leq 1$, which means that only currency circulates. In order to eliminate prices, we substitute (27), (28), (29) and (26) into (25) (pre-multiplied by $\lambda_t \beta^{-t}$), and obtain the following consolidated condition

$$\beta u'(c^1_{t+1})c^1_{t+1} + u'(c^2_t)c^2_t - \alpha(1-h_t) + \alpha b^h_{t+1} - \alpha b^h_t \beta^{-1} \; = \; 0 \qquad (31)$$

Now, if we add the discounted restrictions (31), imposing appropriate terminal conditions, we obtain the implementability constraint

$$u'(c^2_0)c^2_0 - \alpha(1-h_0) + \alpha b_0 \beta^{-1} + \sum_{t=1}^{\infty} \beta^t [u'(c^1_t)c^1_t + u'(c^2_t)c^2_t - \alpha(1-h_t)] \; = \; 0 \qquad (32)$$

We can now define the Ramsey problem as

$$\max \sum_{t=0}^{\infty} \beta^t [u(c^1_t) + u(c^2_t) - \alpha(1-h_t)]$$

subject to (32) and

$$c^1_t + c^2_t + g - (1-h_t) \leq 0 \qquad (33)$$

Let $\gamma \geq 0$ be the Lagrange multiplier associated with the implementability constraint (32). The following equations characterize the Ramsey equilibrium, and show the time inconsistency problem when the price elasticity is different from one (see Nicolini, 1997[7]),

$$I^b_{t+1} = \frac{u'(c^1_{t+1})}{u'(c^2_{t+1})} = \frac{1+\gamma(1-\sigma)}{1+\gamma(1-\sigma)} = 1 \quad t \geq 0 \qquad (34)$$

[7] See also Calvo (1978).

$$\frac{u'(c_0^1)}{u'(c_0^2)} = 1 + \gamma(1-\sigma) \tag{35}$$

$$1 + \tau_t = \frac{u'(c_t^2)}{\alpha} = \frac{1+\gamma}{1+\gamma(1-\sigma)} \quad t \geq 0 \tag{36}$$

It follows that the solution of the Ramsey policy is the Friedman rule and the corresponding equilibrium is stationary from period one on. In the context of optimal taxation rules, the Friedman rule means that the two goods, cash and credit, are taxed at the same rate. This is the optimal solution since the utility function is homothetic in the two goods and separable in leisure. These are the conditions for uniform taxation of Atkinson and Stiglitz (1972), as pointed out by Lucas and Stokey (1983) and Chari, Christiano and Kehoe (1993). Furthermore, if the price elasticity is greater than one ($\sigma < 1$), the consumption in period 0 of the cash good is lower than the consumption from period 1 on. That is, there is a higher tax on the initial cash good (with a price elasticity of one). In summary,

Proposition 4 *Assume* CRRA. *In a Ramsey equilibrium,* $I_{t+1}^b = 1$ *and* $\tau_t = \tau$, $t \geq 0$. *If* $\sigma < 1$ $c_0^1 < c_0^2 = c_{t+1}^2 = c_{t+1}^1$, $t \geq 0$.

This solution is an equilibrium even if electronic money is a liquid asset since the zero profit condition implies that $I_{t+1}^e = I_{t+1}^b - \theta$, $t \geq 0$, and, since $\theta > 0$, the currency printed by the government dominates in rate of return electronic money when the government implements the Ramsey policy; in particular, the nominal interest rate on electronic money is negative. The last argument also shows that there can not be a Ramsey equilibrium in which households only use electronic money (if private financial intermediation is more costly than central bank intermediation) as stated in the following corollary

Corollary 5 *When* $\theta > 0$, *the Ramsey solution is such that* $I_{t+1}^e \leq 1$, $t \geq 0$, *so that electronic money does not circulate.*

Suppose that there was an equilibrium with $I_{t+1}^e > 1$, then $\frac{u'(c_{t+1}^1)}{u'(c_{t+1}^2)} = 1 + \theta$, for $t \geq 0$. However, this relation between cash and credit goods could have been achieved by the "representative government" (in the previous case of $I^e_{t+1} \leq 1$), by setting $I^b_{t+1} = 1 + \theta$, in which case the government would have collected seignorage revenues. As we have seen, with constant elasticity, the government chooses not to impose such a distortion and has less incentive to do so when there are no revenues, as it is the case when agents only use electronic money.

With full commitment, the "representative government" can credibly guarantee that $I^e_t = I^b_t - \theta \leq 1$ and, therefore, he always chooses to exercise this option. That is, with full commitment the analysis of the Ramsey problem reduces to the case, analyzed above, of $I^e_{t+1} \leq 1$.

6.2 Optimal policy without commitment

As we have seen, if $\sigma < 1$, the Ramsey solution is time inconsistent, meaning that money is printed at a rate higher than the one consistent with Friedman rule. Nevertheless, if deviating from such path is costly enough for the "representative" government, then it may be a sequential equilibrium path; that is, it may be a credible policy. We now study under which conditions the Friedman rule is credible.

Proceeding as we have done in Section 4, with the revenue maximizing government, we characterize –for the representative government– the worst sequential equilibrium that can follow a deviation and compare this path with the Ramsey –Friedman rule– path.

Suppose that the government has been following the Ramsey policy up to period t and that its current liabilities –in real terms– are consistent with the Ramsey policy being kept forever –say, d_t. Suppose, furthermore, that if in period $t \geq 1$, the government deviates from the Ramsey policy, by increasing the price level, the private sector reacts immediately and currency is driven out of circulation since only electronic money is demanded. This results in an arbitrarily large price level. This also means that the real value of the outstanding electronic money is also made arbitrarily low. As a result the households are unable to consume the cash good, in that period. Notice that when the private sector only demands electronic money, to set an arbitrarily large price is a best response for the government, as it is for individual private agents not to demand cash after a currency collapse (i.e., the deviation path is Nash and –in the language of Chari and Kehoe– sustainable). Furthermore, if the government policy states that in the event that some private agents demand cash, then it will set prices according to the myopic (period zero) policy (and not according the Friedman rule), then the equilibrium is sub-game perfect, hence –in this context– sequential[8].

To characterize the worst sequential equilibrium, let V_t^W be the value, to the representative government, of the path following a deviation in period t. Since there is no consumption of the cash good (i.e., there is a *currency crunch*), we have that

$$V_t^W = u(0) + u(c(\tau^W)) + \alpha h_t(\tau^W) + \beta W^W(\tau^W)$$

where the following period value, $W^W(\tau^W)$ takes the form

$$W^W(\tau) = [u(c(\tau)) + u(c_\theta(\tau)) + \alpha h_\theta(\tau)]/(1-\beta).$$

Given a tax rate τ, consumptions and labor supplies satisfy:

$$\begin{aligned} u'(c(\tau)) &= \alpha(1+\tau) \qquad (37)\\ u'(c_\theta(\tau)) &= \alpha(1+\tau)(1+\theta)\\ h_t(\tau) &= 1-(c(\tau)+g) \end{aligned}$$

and

$$h_\theta(\tau) = 1-(c(\tau)+(1+\theta)c_\theta(\tau)+g)$$

Finally, the tax rate τ^W must satisfy

$$g = \beta\tau^W c_\theta(\tau^W) + \tau^W c(\tau^W) - (1-\beta)d_t\beta^{-1} \qquad (38)$$

Similarly, we can compute the value of the Ramsey path at $t \geq 1$,

$$V_t^R = 2u(c(\tau^R)) + \alpha h(\tau^R) + \beta W^R(\tau^R)$$

[8]See Benhabib *et al.*(1997) for a similar characterization of credible policies (notice, however, that our equilibrium is not *perfect* in the Benhabib *et al.* sense).

where,

$$W^R(\tau) = [2u(c(\tau)) + \alpha h(\tau)]/(1-\beta)$$

and, given a tax rate τ, consumptions and labor supplies must satisfy (37) and

$$h(\tau) = 1 - (2c(\tau) + g)$$

Finally, in order to compute the "Ramsey tax" τ^R we need to know the consumption of the cash good and labor supply in period zero: $c_0(\tau), h_0(\tau)$. They are given by

$$u'(c_0(\tau)) = \frac{\alpha(1+\tau)\sigma}{1-(1-\sigma)(1+\tau)} \tag{39}$$

and

$$h_0(\tau) = 1 - (c_0(\tau) + c(\tau) + g)$$

It follows that the consumption tax of the Ramsey solution is the value τ^R that satisfies

$$g = \beta\tau^R 2c(\tau^R) + (1-\beta)\tau^R(c_0(\tau^R) + c(\tau^R)) - (1-\beta)((1+\tau^R)c_0(\tau^R) + d_0\beta^{-1})$$

Notice that one can account for the possible interest of the "representative government" in deviating in period t by comparing the resulting budgets in that period. As we have just seen, the budget corresponding to the worst sequential equilibrium path is (38), i.e.

$$g = \beta\tau^D c_\theta(\tau^D) + \tau^D c(\tau^D) - (1-\beta)d_t\beta^{-1}$$

while the present value budget of following the Ramsey path is

$$g = 2\tau^R c(\tau^R) - (1-\beta)(1+\tau^R)c(\tau^R) - (1-\beta)d_t\beta^{-1} \tag{40}$$

There are three differences between (38) and (40). The first is that $c_\theta(\tau^D)$ shows up instead of $c(\tau^R)$. This reflects the fact that after a deviation, consumers use electronic money to buy the cash good, which is dominated by currency at the Ramsey equilibrium. Therefore, consumption of the cash good following a deviation is lower than at the Ramsey solution. Note that this means that as the tax base will be lower, the tax rate must be higher, everything else constant. The second is that since, after a deviation, there is a –one period– *liquidity crunch*, the government cannot collect consumption taxes from the cash good in the period t. Thus, the value of the tax revenues is discounted by β. This also means that the tax base is lower, such that everything else constant, the tax must be higher. Finally, the third difference is that the second term in the right-hand-side of (40) is not present in (38). This is precisely the benefit of the deviation, the destruction of the real value of outstanding currency. In this case, everything else constant, the after deviation tax must be lower. Note that if the two first effects dominate, the tax after a deviation is higher than the Ramsey tax, so a deviation lowers the utility of the government, which means that the Ramsey allocation is sustainable. An example is when β is made arbitrarily close to one. Then, it must be that $\tau^R \leq \tau^D$, with equality when θ is made arbitrarily close to zero. In the case of equality, the value of the deviation is lower than the value of the Ramsey solution because of the *liquidity crunch.*

When the gains from the initial destruction of real liabilities are enough to induce $\tau^R > \tau^D$, then this effect must be compared with the costs of making the consumption of the cash good too low – the *liquidity crunch*–, as well as the waste in resources from using electronic money in transactions rather than using the more efficient currency. If the costs outweigh the benefits, $V_t^R \geq V_t^{RW}$, the Ramsey solution is a sequential equilibrium path. In particular, the Friedman rule is sustainable if the discount factor and the intermediation costs are not too low and the *liquidity crunch* factor, from having $u(0)$ instead of $u(c(\tau^R)$, results in a severe loss of utility.

Reserve requirements have no effect on the Ramsey solution. This solution is the Friedman rule and electronic money does not circulate. However, the presence of the reserve requirements can increase the punishment, to the disutility of autarchy, since this would be an equilibrium with an arbitrarily large nominal interest rate. This would help sustain the commitment solution.

In summary, when governments are benevolent, electronic money reduces the punishment of a deviation and therefore makes it harder to sustain the optimal solution. However, the punishment might still be severe enough, so that the Friedman rule can still be the outcome of a sequential equilibrium.

7 Concluding remarks

In this paper we have seen how the role of electronic money competition (and of similar "money substitutes") as a disciplinary mechanism is fairly different depending on: the relative efficiency of financial intermediaries, the preferences of the government and its ability to commit, and the extent of reserve requirements restrictions.

The introduction of electronic money affects the returns of the profit maximizing government by competing away some of the monopolistic rents and, as a result, lowering the equilibrium inflation rates in the full commitment equilibrium. When there is not full commitment, the cost for a profit maximizing government from deviating, by defaulting on current cash balances (i.e., government liabilities), is simply the loss of future seignorage rents. The presence of electronic money does not affect the revenues of the government after a deviation, since the seignorage revenues are zero independently of whether households can or can not substitute currency for other liquid assets. However, with lower gains — due to the presence of electronic money— the relative cost of a deviation is also lower and, hence, higher the incentive to deviate. Nevertheless, if financial intermediation is costly enough, a profit maximizer government will not deviate from the full commitment path.

In contrast, with a "representative" government, the introduction of electronic money does not affect the returns of the government since, under full commitment, the Ramsey policy prescription is the Friedman rule and electronic money is –asset return– dominated by the government currency. In our model, it follows from standard optimal taxation principles that the Ramsey policy is time-inconsistent. The presence of electronic money affects the value –to the government– of the equilibrium path after a deviation. Since the government shares the preferences of the household, and the household is better off when it is able to consume cash goods with electronic money than in autarchy (and, furthermore, the tax base is wider), the "punishment" after a deviation is not so severe. Therefore, the incentive to deviate from the Friedman rule is higher, when there is electronic money. But, as we have seen, the *liquidity crunch* effect may be enough of a deterrence to prevent the "representative" government to deviate from the Ramsey policy even when there is electronic money.

In both cases, whether the government is "representative" or profit maximizer, if a deviation from the full commitment solution takes place (because the deterrence effects are not strong enough), households are better off if electronic money is in existence (e.g., the relation between cash and credit goods is less distorted). There is, however, a region of parameters where deviations will take place with electronic money and will not take place without its presence. Only in this region may a world without electronic money be preferred by households.

Reserve requirements affect the competition between currency and electronic money. With reserve requirements the rents in the full commitment solution with a revenue maximizing government are higher, and the costs of a deviation from the Friedman rule path with a welfare maximizing government are also higher. So reserve requirements make it easier to sustain the commitment solutions, which may result in a welfare improvement, when the government is revenue maximizer. Similarly, reserve requirements can make the deviation paths more harmful to a "representative" government, in the presence of electronic money. That is, our analysis also provides prescriptions for the use of reserve requirements as policy instruments, even if our deterministic, perfect information, economies are absent of the problems that usually justify their existence.

While this paper suggests many new inquires, there is one, in particular, that we are pursuing: the analysis of "currency competition" in its strict sense. With this our analysis will be in closer line with the historical debate on currency competition (see White, 1993) and will also provide more general insights on how competition and reputation –as disciplinary mechanisms– may interact in a given market structure.

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